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Project: **Large Hadron Collider**
Second Line: **Interaction Region Feedbox Test**

Procedure for Installation and Test of 7500 A Leads for the DFBX

MAG

1. Scope

This procedure applies to testing the first pair of 7500 A current leads with HTS lower sections. The current leads are manufactured by Pirelli under Lawrence Berkeley National Laboratory subcontract 6499152. The testing will be performed for LBNL at CERN. The current lead must satisfactorily pass these tests before a Production Readiness Review can be held to authorize the final production of 20 pair.

2. Documents

LBNL Documents

LBNL Specification M923B, "7500 A Current Leads Using High Temperature Superconductor for LHC Inner Triplet Magnets", 6 August, 2001.

Pirelli Drawings

7.5kA Current Lead Assembly	LBNL01
7.5kA Current Lead Instrumentation Details	LBNL39

3. Incoming Inspection of P1 (ICP)

Note: Save the shipping container for sending the leads to Berkeley after the tests are completed.

3.1 Examination of Pirelli Inspection & Test Records
Complete _____ Incomplete _______ Not Shipped ________

3.2 Note condition of shipping container
No Damage _____ Slight Damage _____ Massive Damage ______

3.3 Note general condition of leads in container
Good Condition _____ Damaged areas _________

3.4 Examine condition of g-load indicators
Not Tripped _____ Tripped _____

3.5 Dimensional Checks (reference Pirelli dwg LBNL01)
Orientation of warm terminal (item 5) as required?
yes _____ no, describe _____
Orientation of mounting flange (item 6) as required?
yes _____ no, describe _____
Item 6 conflat knife edge okay?
yes _____ no, describe _____
Lead Body (Item 8) perpendicularity w.r.t. top flange within 0.13 mm?
yes _____ no, value is _____
Is 20 K inlet on opposite side of warm terminal?
yes _____ no, describe ___

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Is 20 K inlet 502 mm below top flange?
yes _____ no, value is _____
LBNL seal flange 560/562 mm below top flange?
yes _____ no, value is _____
LBNL seal flange perpendicular to Lead Body (Item 8) within 0.13 mm?
yes _____ no, value is _____
LBNL seal flange surface flat within 0.05 mm?
yes _____ no, value is _____
LBNL Seal flange surface finish okay?
yes _____ no, value is _____
LBNL seal flange outer diameter 130 mm?
yes _____ no, value is _____
LBNL seal flange parallel to large seal flange (Item6) within 0.25 mm?
yes _____ no, value is _____
Length of HTS section 455 mm as required?
yes _____ no, value is _____
HTS section concentric to item 8 within 0.25 mm?
yes _____ no, value is _____
Overall length 1450 mm?
yes _____ no, value is _____
Max LHe level 90 mm from bottom?
yes _____ no, value is _____
Min LHe level 50 mm from bottom?
yes _____ no, value is _____

3.6 Voltage Tap Checks (6-pin receptacles, reference Pirelli dwg LBNL39)
Use a multimeter
PG-1 Continuity to warm terminal:
Pin 1: yes _____ no _____ Pin 2: yes _____ no _____
Pin 3: yes _____ no _____ Pin 4: yes _____ no _____
Pin 5: yes _____ no _____
PG-2 Continuity to warm terminal:
Pin 1: yes _____ no _____ Pin 2: yes _____ no _____
Pin 3: yes _____ no _____ Pin 4: yes _____ no _____
Pin 5: yes _____ no _____
PG-1, Pin 6 Isolation from terminal > 10 kohms? yes _____ no, value _____
PG-2, Pin 6 Isolation from terminal > 10 kohms? yes _____ no, value _____

3.7 Thermometer Checks (16-pin receptacle, reference Pirelli dwg LBNL39)
use a multimeter
Pin 1 – Pin 5 > 10 kohms? yes _____ no, value _____

Pin 1 – Pin 9 > 10 kohms? yes _____ no, value _____
Pin 1 – Pin 3 < 10 ohms? yes _____ no, value _____
Pin 2 – Pin 4 < 10 ohms? yes _____ no, value _____
Pin 5 – Pin 7 < 10 ohms? yes _____ no, value _____
Pin 6 – Pin 8 < 10 ohms? yes _____ no, value _____
Pin 9 – Pin 11 < 10 ohms? yes _____ no, value _____
Pin 10 – Pin 12 < 10 ohms? yes _____ no, value _____
Pin 1 – Pin 2 ≅ 100 ohms? yes _____ no, value _____
Pin 5 – Pin 6 ≅ 100 ohms? yes _____ no, value _____
Pin 9 – Pin 10 ≅ 100 ohms? yes _____ no, value _____

4. Incoming Inspection of P2 (ICP)

4.1 Examination of Pirelli Inspection & Test Records
Complete _____ Incomplete _______ Not Shipped ________

4.2 Note condition of shipping container
No Damage _____ Slight Damage _____ Massive Damage ______

4.3 Note general condition of leads in container
Good Condition _____ Damaged areas _________

4.4 Examine condition of g-load indicators
Not Tripped _____ Tripped _____

4.5 Dimensional Checks (reference Pirelli dwg LBNL01)
Orientation of warm terminal (item 5) as required?
yes _____ no, describe _____
Orientation of mounting flange (item 6) as required?
yes _____ no, describe _____
Item 6 conflat knife edge okay?
yes _____ no, describe _____
Lead Body (Item 8) perpendicularity w.r.t. top flange within 0.13 mm?
yes _____ no, value is _____
Is 20 K inlet on opposite side of warm terminal?
yes _____ no, describe _____
Is 20 K inlet 502 mm below top flange?
yes _____ no, value is _____
LBNL seal flange 560/562 mm below top flange?
yes _____ no, value is _____
LBNL seal flange perpendicular to Lead Body (Item 8) within 0.13 mm?
yes _____ no, value is _____
LBNL seal flange surface flat within 0.05 mm?
yes _____ no, value is _____
LBNL Seal flange surface finish okay?
yes _____ no, value is _____

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LBNL seal flange outer diameter 130 mm?
yes _____ no, value is _____
LBNL seal flange parallel to large seal flange (Item6) within 0.25 mm?
yes _____ no, value is _____
Length of HTS section 455 mm as required?
yes _____ no, value is _____
HTS section concentric to item 8 within 0.25 mm?
yes _____ no, value is _____
Overall length 1450 mm?
yes _____ no, value is _____
Max LHe level 90 mm from bottom?
yes _____ no, value is _____
Min LHe level 50 mm from bottom?
yes _____ no, value is _____

4.6 Voltage Tap Checks (6-pin receptacles, reference Pirelli dwg LBNL39)
Use a multimeter
PG-1 Continuity to warm terminal:
Pin 1: yes _____ no _____ Pin 2: yes _____ no _____
Pin 3: yes _____ no _____ Pin 4: yes _____ no _____
Pin 5: yes _____ no _____
PG-2 Continuity to warm terminal:
Pin 1: yes _____ no _____ Pin 2: yes _____ no _____
Pin 3: yes _____ no _____ Pin 4: yes _____ no _____
Pin 5: yes _____ no _____
PG-1, Pin 6 Isolation from terminal > 10 kohms? yes _____ no, value _____
PG-2, Pin 6 Isolation from terminal > 10 kohms? yes _____ no, value _____

4.7 Thermometer Checks (16-pin receptacle, reference Pirelli dwg LBNL39)
use a multimeter
Pin 1 – Pin 5 > 10 kohms? yes _____ no, value _____
Pin 1 – Pin 9 > 10 kohms? yes _____ no, value _____
Pin 1 – Pin 3 < 10 ohms? yes _____ no, value _____
Pin 2 – Pin 4 < 10 ohms? yes _____ no, value _____
Pin 5 – Pin 7 < 10 ohms? yes _____ no, value _____
Pin 6 – Pin 8 < 10 ohms? yes _____ no, value _____
Pin 9 – Pin 11 < 10 ohms? yes _____ no, value _____
Pin 10 – Pin 12 < 10 ohms? yes _____ no, value _____
Pin 1 – Pin 2 ≅ 100 ohms? yes _____ no, value _____
Pin 5 – Pin 6 ≅ 100 ohms? yes _____ no, value _____
Pin 9 – Pin 10 ≅ 100 ohms? yes _____ no, value _____

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5. Mechanical Integration of Current Leads in Test Facility (ACR)

5.1 Suspend Lead at angle of 10°, or tilt test chamber by -10° with leads vertical.
5.2 Attach baffle assembly to lead body (Item 8) per instructions from Y. Kajiyama
5.3 Remove cover plates from LBNL test chambers

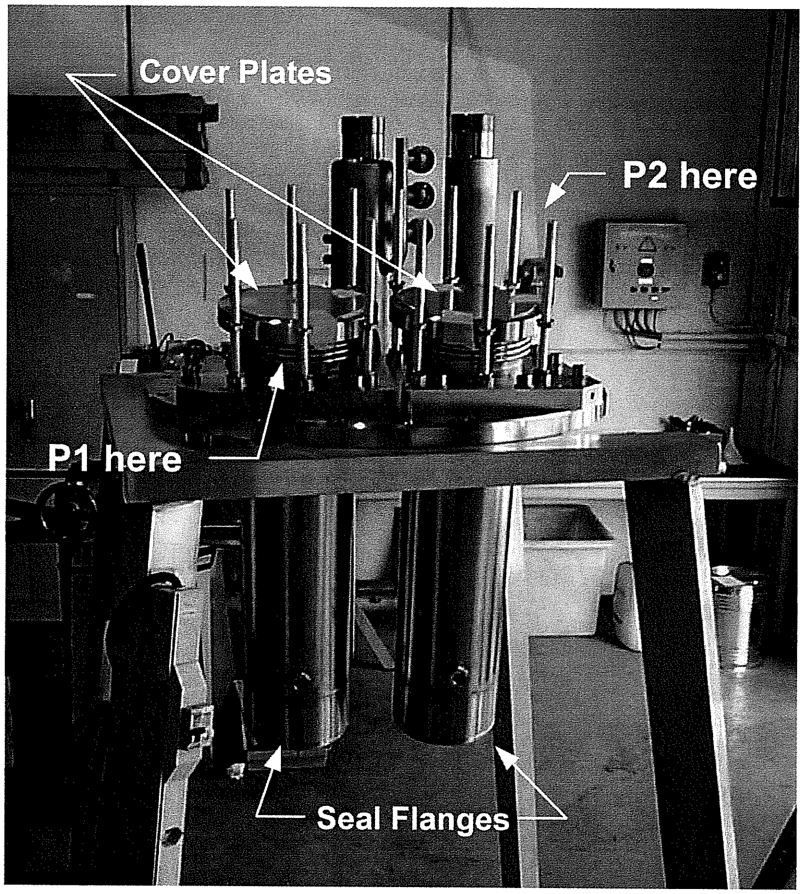

Figure 5.8. LBNL Test chambers installed in CERN top flange.

5.4 Clean sealing flanges inside the chambers with acetone and/or alcohol wipe
5.5 Position Peek seal and insulators in each chimney according to Fig 5.5. *Note bellows are not present in CERN test chimney.*

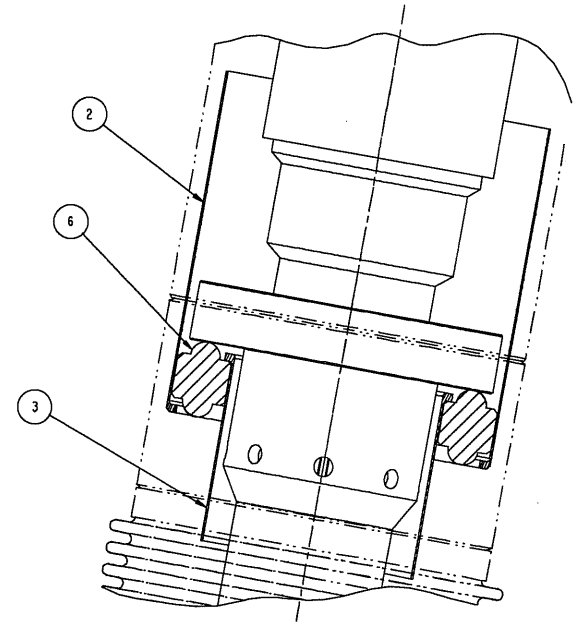

Figure 5.5; 2 – Upper Insulator, 3 – Lower Insulator, 6 – PEEK Seal

5.6 Clean test facility Conflat flange knife edge and LBNL-provided copper gasket. Install gasket on Conflat flange. Align rotatable conflat flange to orientation shown on Figure 5.6.

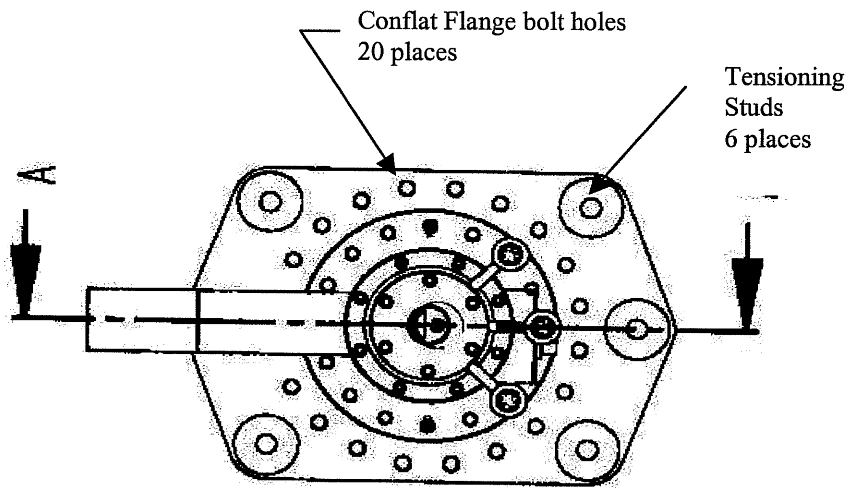

Figure 5.6. 20-hole conflat bolt pattern is bisected by center tensioning studs.

5.7 Install Pirelli Leads per Figure 5.7. Install P1 on the left hand side of picture 5.3 and P2 on the right hand side. Note: if there is a gap between the test facility Conflat flange and the Pirelli flange, pull the bellows up and close the gap. Use the nuts on the tensioning studs to hold the lead in place while the 20 conflat bolts are tightened. Use the 12-point bolts and wrench provided by LBNL to connect the flanges. **The bolts are not metric.**

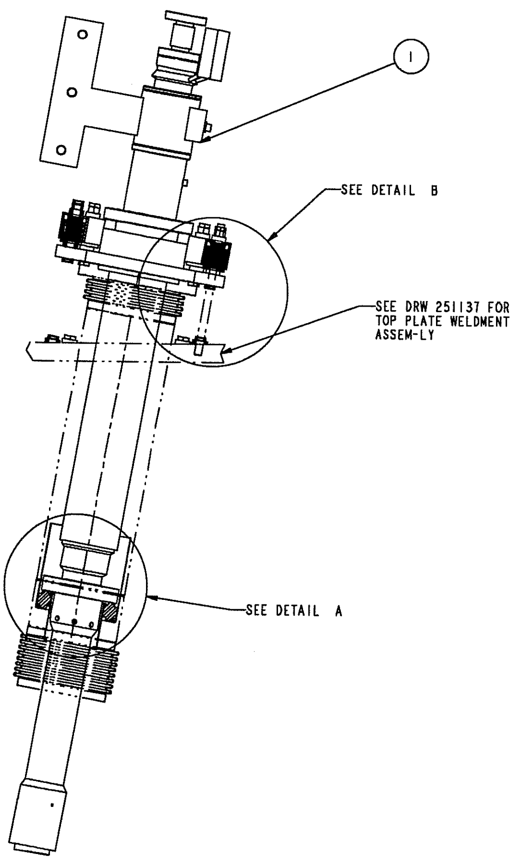

Figure 5.7. HTS Lead in Test Chimney. Note: CERN chimneys do not have bellows.

5.8 Install Bellville Washer Assemblies on each tensioning stud per Figure 5.8. In the figure: Item 11 (10 each) are Belleville Washers, arranged as shown; Item 6 (2 each) are flat washers; Items 4 and 5 are the Belleville Washer Holder; Item 10 Spherical Washers are above and below the washer holder; Item 9 is loading nut; Item 8 is a jam nut.

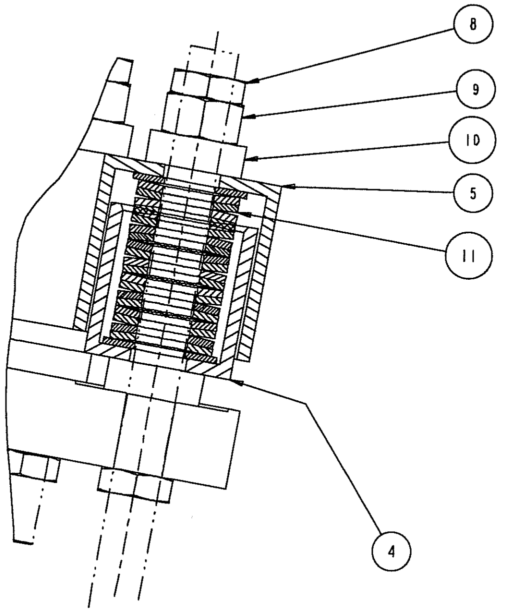

Figure 5.8. Belleville Washer Assembly.

5.9 Tighten the 6 Belleville Washer Assemblies to apply load to the PEEK seal.

5.9.1 Washers for Lead P1

5.9.1.1 Ensure that the nuts used in 5.7 above have a gap of about 5 mm below the lead flange.

5.9.1.2 Roughly center the lower end of the lead in the chimney. Use Teflon, other soft shims, or coworker hold in place as needed to keep it in position.

5.9.1.3 Tighten the 6 loading nuts finger-tight. Measure and record the gap between Item 4 (in Figure 5.8) and the current lead top plate at the 6 locations.

A _______ B ______ C ______ D ______ E ______ F ______

5.9.1.4 Using the sequence A through F in figure 5.9, tighten the nuts ¼ turn until the total compression is 1.8 mm. Record measurements below.

A _______ B ______ C ______ D ______ E ______ F ______

A _______ B ______ C ______ D ______ E ______ F ______

A _______ B ______ C ______ D ______ E ______ F ______

A _______ B ______ C ______ D ______ E ______ F ______

A _______ B ______ C ______ D ______ E ______ F ______

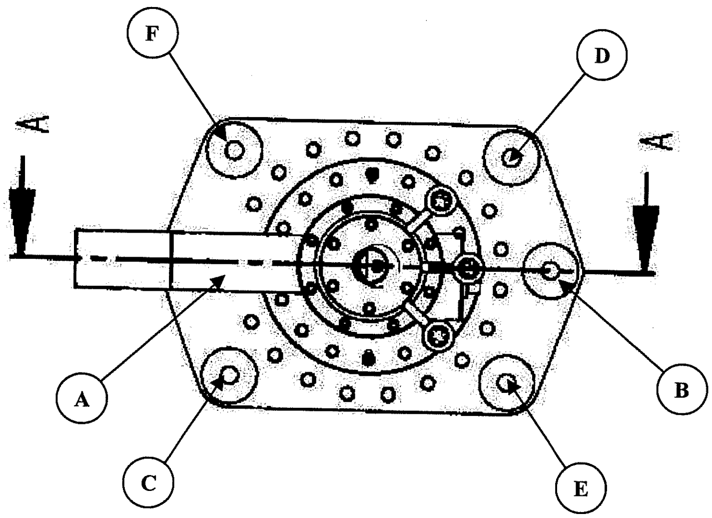

Figure 5.9

5.9.2 Washers for Lead P2

5.9.2.1 Ensure that the nuts used in 5.7 above have a gap of about 5 mm below the lead flange.

5.9.2.2 Roughly center the lower end of the lead in the chimney. Use Teflon, other soft shims, or coworker hold in place as needed to keep it in position.

5.9.2.3 Tighten the 6 loading nuts finger-tight. Measure and record the gap between Item 4 (in Figure 5.8) and the current lead top plate at the 6 locations.

A _______ B ______ C ______ D ______ E ______ F ______

5.9.2.4 Using the sequence A through F in figure 5.9, tighten the nuts ¼ turn until the total compression is 1.8 mm. Record measurements below.

A _______ B ______ C ______ D ______ E ______ F ______

A _______ B ______ C ______ D ______ E ______ F ______

A_______ B______ C______ D______ E______ F______

A_______ B______ C______ D______ E______ F______

A_______ B______ C______ D______ E______ F______

5.10 Tighten down the jam nuts to secure the loading nuts. Tighten the nuts on the underside of the current lead top plate against the plate to provide stability during transportation.

5.11 Attach the copper bus bar adapter provided by LBNL as shown in Figure 5.11 to allow eventual connection to the CERN power converter. Bolts are to be provided by CERN. It is recommended to use Penetrox-E or equivalent material in the joint to promote good electrical conductivity.

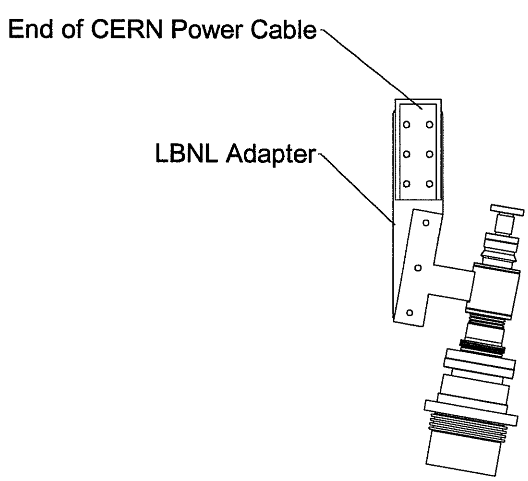

Figure 5.11. Warm End Termination.

6. Electrical Integration of Current Leads in Test Facility (ICP)

6.1 Make connection to LTS pigtails. Use a "Praying Hands" type joint 120 mm-long as shown in Figures 6.1-1 and 6.1-2. The ends of the LTS pigtails are individually pretinned for about 120 mm by Pirelli, and the joint is a mechanical connection with indium foil (supplied by LBNL) between the cables to ensure good electrical connection. The conductors are arranged in a spiral path so the NbTi cables in the joint are facing each other, with the copper cables against the stainless steel mechanical clamp. Note: Lionel Metral has the stainless steel mechanical clamp locked in his cabinet in B276.

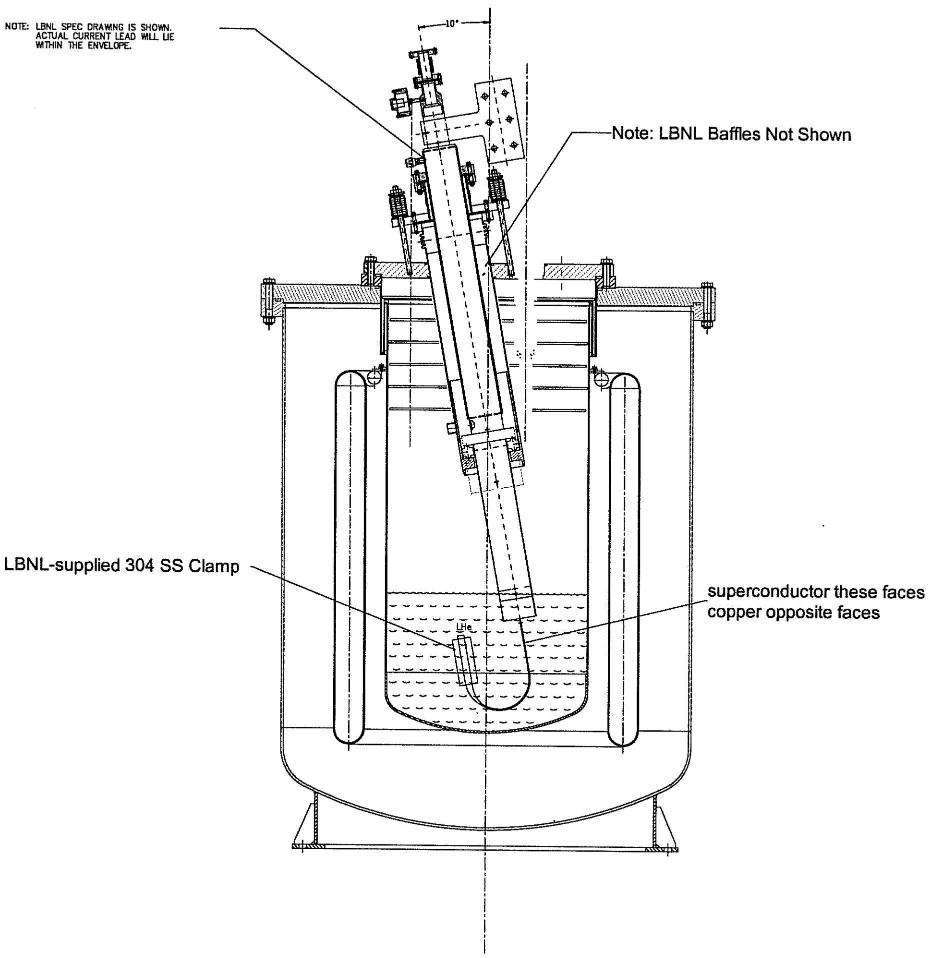

Figure 6.1-1 Side View of Lead in Cryostat with the LTS cables connected in a "Praying Hands Type Joint.

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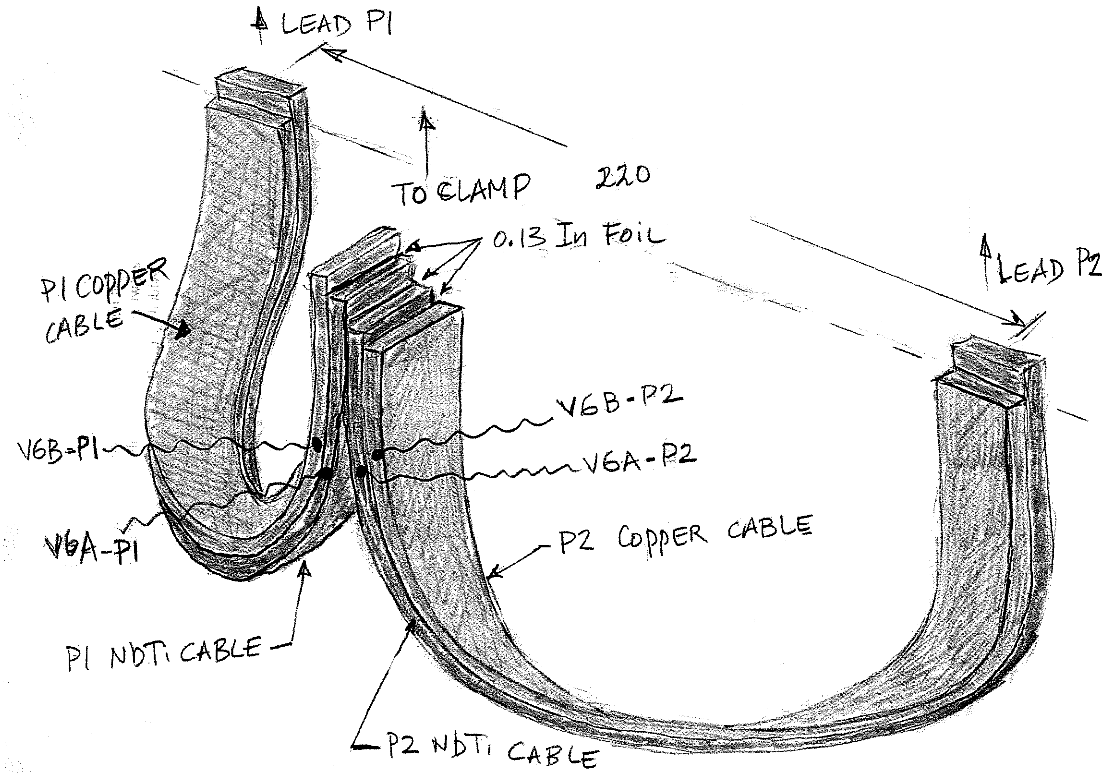

Figure 6.1-2. Illustration of LTS Pigtail Routing to Praying Hands Joint.

6.2 Attach the voltage tap wires labeled "V6" to the LTS cables as indicated on Fig 6.1-2.
6.3 Insulate the conductor as needed with Kapton tape, and secure it with Kevlar string and/or G-10 support plates.
6.4 Adjust position of LHe level sensors so the level can be controlled with respect to the maximum and minimum LHe levels marked on the current leads
6.5 Install assembly into test dewar
6.6 Connect current lead diagnostic cables to current lead and equipment
6.7 Pass 10 A DC through the current lead and verify proper reading of voltage taps. Record pin-pin voltages in table.

Lead P1		Lead P2	
PG-1	PG-2	PG-1	PG-2
1 – 2 = ______ mV	1 – 2 = ______ mV	1 – 2 = ______ mV	1 – 2 = ______ mV
1 – 3 = ______ mV	1 – 3 = ______ mV	1 – 3 = ______ mV	1 – 3 = ______ mV
1 – 4 = ______ mV	1 – 4 = ______ mV	1 – 4 = ______ mV	1 – 4 = ______ mV

1 – 5 = ______ mV	1 – 5 = ______ mV	1 – 5 = ______ mV	1 – 5 = ______ mV
1 – 6 = ______ mV	1 – 6 = ______ mV	1 – 6 = ______ mV	1 – 6 = ______ mV

6.8 **Disconnect the current lead voltage tap and thermometer cables.**
Purge and backfill the LHe chamber and verify that the lead can withstand 1.5 kV to ground with the chamber pressurized with warm, pure helium gas at 1.3 bar. Record the leakage current after 1 minute. __________ microamps.
Reconnect the current lead voltage tap and thermometer cables.

6.9 Connect the lead warm terminal heater wires to a CERN-supplied wall plug for connection to 240V AC power. The heaters have an internal thermostat to automatically turn the heaters on and off to control the temperature. Make provision for measuring heater power, such as with a clamp on ammeter.

6.10 Hookup the high-current power cables to warm terminals as indicated in Fig 5.11. Use Penetrox E or equivalent material in the joint to promote electrical conductivity.

6.11 Verify that the CERN protection system is properly connected.

7. Cooldown (ACR & ICP)

7.1 Before cooldown, loosen the nuts on the underside of the lead plate that were tightened in 5.10 at least 0.5 mm below the top plate.

7.2 Use cooldown procedure developed for the 13 kA HTS Prototype Leads

8. Current Lead Verification Testing (FNAL, ICP, ACR)

8.1 Measurements in stand-by operation (performed in the night). Measurement of: heat load into the helium bath, 20 K helium flow rate and pressure drop with different temperatures at the warm end of the HTS (T_{HTS} = 40 K and 50 K). The 20 K helium flow is controlled by T_{HTS}. Also monitor heater duty cycle.

8.2 Measurements with current.

8.2.1 The current is increased up to 7500 A with the nominal ramp rate of 100 A/sec (during the first ramp, the current is increased by step of 1000 A).

8.2.2 Measurement of: contact resistances, voltage drop across resistive heat exchanger, 20 K helium flow rate and pressure drop with different temperatures at the warm end of the HTS (T_{HTS} = 40 K and 50 K). The 20 K helium flow is controlled by T_{HTS}. Definition of nominal T_{HTS}. Compare the thermal time constant of T1 vs. T2.

8.2.3 Run for several hours at 7500 A current with 20 K helium flow controlled by nominal T_{HTS} (definition of nominal flow). Use both T1 and T2 to get comparison of thermal time constant.

8.2.4 Run for several hours at 7500 A current and 20 K helium flow constant and equal to the nominal one.

8.2.5 Run for 24 hours at 7500 A current and 20 K helium 5 % lower than nominal one. T3 shall not exceed 350 K.

8.2.6 Run at currents of 4000 A and 6000 A for several hours at each current. (Measurement of 20 K helium flow rate and voltage drop across the resistive heat exchanger).

8.2.7 Run with inlet gas temperature around 10K, and current of 4000 A and 7500 A for several hours at each current. (Measurement of 20 K helium flow rate and voltage drop across the resistive heat exchanger).

8.3 Transient operation.

8.3.1 Loss of 20 K helium flow measurement: in operating conditions (nominal flow and 7500 A current), the liquid helium level is dropped to the LTS cable and the valve supplying the 20 K helium flow is closed and, within 5 seconds from the detection of the coolant loss, the current is made to decay exponentially with a 10 second time constant. During the discharge, the temperature at the warm end of the HTS element must remain below its critical value. (No quench)

8.4 Quench measurement

8.4.1 The temperature at the warm end of the superconductor is brought to its critical value via a heater in the 20K coolant line. The quench detection signal is the voltage drop across the HTS element. When it reaches the critical value (specified to be 100 mV or greater), indicating a resistive transition of the superconductor, the current is made to decay exponentially with a 10-second time constant. The resulting ohmic heating must not damage or modify the properties of any part of the lead (maximum peak of temperature specified for the LBL HTS prototype leads equal to 200 K).

9. Supplementary Tests

9.1 Thermal Cycling tests – need to define and negotiate time with CERN.

10. Warmup, remove leads from test facility, replace in shipping container and forward to Berkeley if tested okay, otherwise ship to Pirelli for reworking.

Appendix A. Pirelli Drawings

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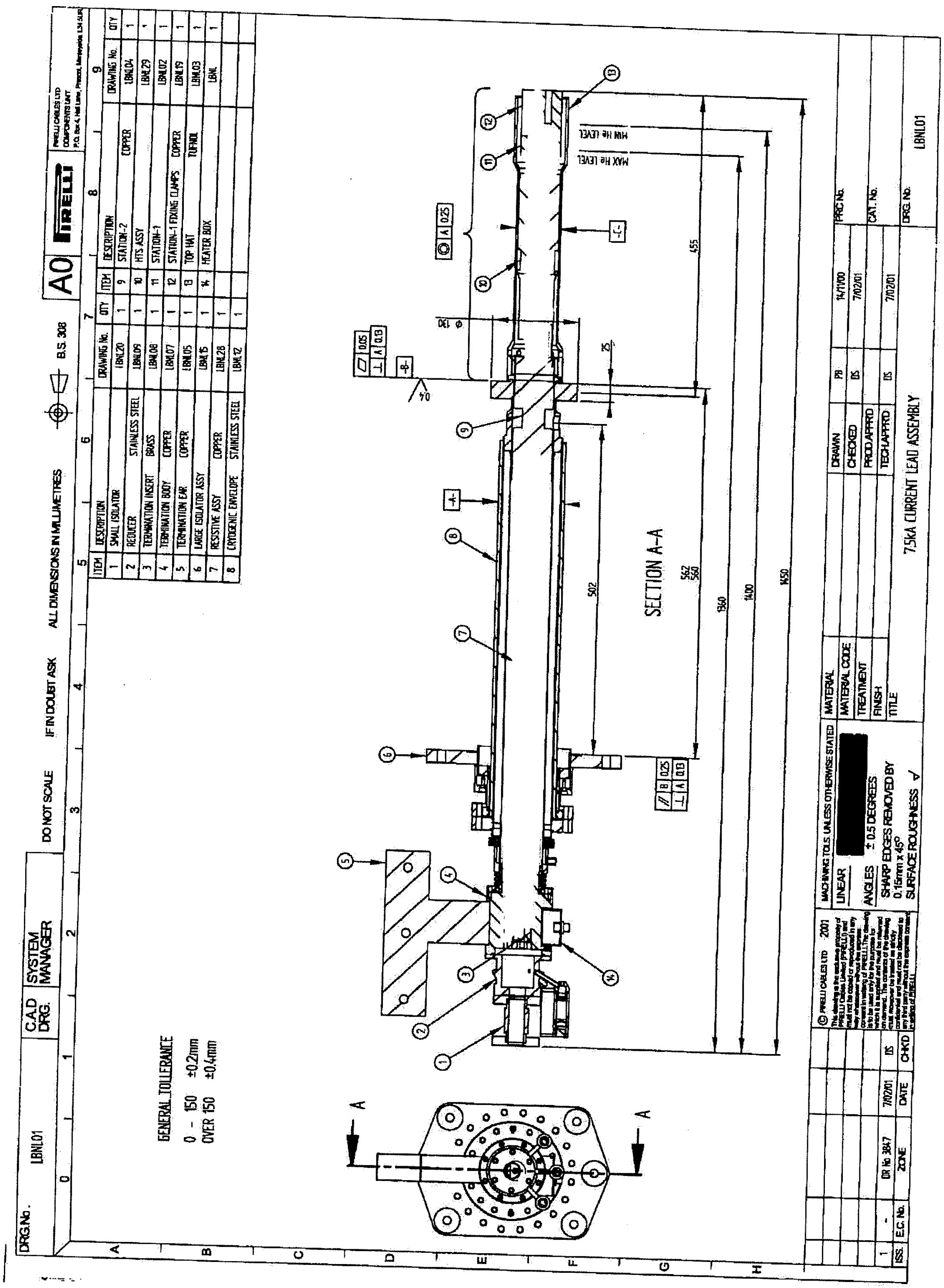
Date **November 1, 2001**



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Department **Mechanical Engineering** | Date **November 1, 2001**